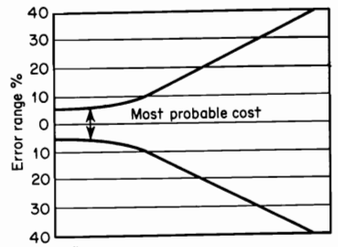
CHEMICAL
ENGINEERING
SERIES



Required information		Detailed estimate ±5% range	Definitive estimate ±10% range	Preliminary estimate ±20% range	Study estimate ±30% range	Order-of-magnitude estimate >±30% range
Site	Location	•	•	•	•	
	General description	•	•	•		
	Soil bearing	•	•	•		
	Location & dimensions R.R., roads, impounds, fences	•	•	•		
	Well-developed site plot plan & topographical map	•	•			
	Well-developed site facilities	•				
Process flow sheet	Rough sketches				•	
	Preliminary			•		
	Engineered	•	•			
Equipment list	Preliminary sizing & material specifications			•	•	
	Engineered specifications	•	•			
	Vessel sheets	•	•			
	General arrangement					
	(a) Preliminary		•	•		
	(b) Engineered	•				
Building and structures	Approximate sizes & type of construction			•	•	
	Foundation sketches		•	•		
	Architectural & construction	•	•	•		
	Preliminary structural design			•		
	General arrangements & elevations	•	•			
	Detailed drawings	•				
Utility requirements	Rough quantities (steam, water, electricity, etc.)				•	
	Preliminary heat balance			•		
	Preliminary flow sheets			•		
	Engineered heat balance	•	•			
	Engineered flow sheets	•	•			
	Well-developed drawings	•				
Piping	Preliminary flow sheet & specifications			•	•	
	Engineered flow sheet	•	•			
	Piping layouts & schedules	•				
Insulation	Rough specifications			•		
	Preliminary list of equipment & piping to be insulated		•			
	Insulation specifications & schedules	•	•			
	Well-developed drawings or specifications	•				
Instrumentation	Preliminary instrument list			•		
	Engineered list & flow sheet	•	•			
	Well-developed drawings	•				
Electrical	Preliminary motor list-approximate sizes			•	•	
	Engineered list & sizes	•	•			
	Substations, number & sizes, specifications	•	•	•		
	Distribution specifications	•				
	Preliminary lighting specifications			•		
	Preliminary interlock, control, & instrument wiring specs.		•			
	Engineered single-line diagrams (power & light)	•	•			
	Well-developed drawings	•				
Man-hours	Engineering & drafting	•	•	•	•	
	Labor by craft	•				
	Supervision	•				
Project scope standard processes	Product, capacity, location & site requirements. Utility & service requirements. Building & auxiliary requirements. Raw materials & finished product handling & storage requirements					•

Figure 5-4 Cost-estimating information guide.

Table 2 Typical average costs for making estimates (1979)†

Cost of project	Less than $2,000,000	$2,000,000 to $10,000,000	$10,000,000 to $100,000,000
Order-of-magnitude estimate	$ 2,000	$ 4,000	$ 8,000
Study estimate	12,000	25,000	35,000
Preliminary estimate	30,000	50,000	80,000
Definitive estimate	50,000	100,000	200,000
Detailed estimate	130,000	320,000	630,000

† Adapted from A. Pikulik and H.E. Diaz, Cost Estimating for Major Process Equipment, *Chem. Eng.*, 84(21): 106 (Oct. 10, 1977).

an envelope of variability. There is a large probability that the actual cost will be more than the estimated cost where information is incomplete or in time of rising-cost trends. For such estimates, the positive spread is likely to be wider than the negative, e.g., +40 and −20 percent for a study estimate. Table 2 illustrates the wide variation that can occur in the cost of making a capital-investment estimate depending on the type of estimate.

Predesign cost estimates (defined here as order-of-magnitude, study, and preliminary estimates) require much less detail than firm estimates such as the definitive or detailed estimate. However, the predesign estimates are extremely important for determining if a proposed project should be given further consideration and to compare alternative designs. For this reason, most of the information presented in this chapter is devoted to predesign estimates, although it should be understood that the distinction between predesign and firm estimates gradually disappears as more and more detail is included.

It should be noted that the predesign estimates may be used to provide a basis for requesting and obtaining a capital appropriation from company management. Later estimates, made during the progress of the job, may indicate that the project will cost more or less than the amount appropriated. Management is then asked to approve a *variance* which may be positive or negative.

COST INDEXES

Most cost data which are available for immediate use in a preliminary or predesign estimate are based on conditions at some time in the past. Because prices may change considerably with time due to changes in economic conditions, some method must be used for updating cost data applicable at a past date to costs that are representative of conditions at a later time.† This can be done by the use of cost indexes.

† See Chap. 10 for a discussion of the strategy to use in design estimates to consider the effects of inflation or deflation on costs and profits in the future.

A cost index is merely an index value for a given point in time showing the cost at that time relative to a certain base time. If the cost at some time in the past is known, the equivalent cost at the present time can be determined by multiplying the original cost by the ratio of the present index value to the index value applicable when the original cost was obtained.

$$\text{Present cost} = \text{original cost}\left(\frac{\text{index value at present time}}{\text{index value at time original cost was obtained}}\right)$$

Cost indexes can be used to give a general estimate, but no index can take into account all factors, such as special technological advancements or local conditions. The common indexes permit fairly accurate estimates if the time period involved is less than 10 years.

Many different types of cost indexes are published regularly.† Some of these can be used for estimating equipment costs; others apply specifically to labor, construction, materials, or other specialized fields. The most common of these indexes are the *Marshall and Swift all-industry and process-industry equipment indexes*, the *Engineering News-Record construction index*, the *Nelson refinery construction index*, and the *Chemical Engineering plant cost index*. Table 3 presents a list of values for various types of indexes over the past 15 years.

Marshall and Swift Equipment Cost Indexes‡

The Marshall and Swift (formerly known as Marshall and Stevens) equipment indexes are normally divided into two categories. The all-industry equipment index is simply the arithmetic average of the individual indexes for 47 different types of industrial, commercial, and housing equipment. The process-industry equipment index is a weighted average of eight of these, with the weighting based on the total product value of the various process industries. The percentages used for the weighting in a typical year are as follows: cement, 2; chemicals, 48; clay products, 2; glass, 3; paint, 5; paper, 10; petroleum, 22; and rubber, 8.

The Marshall and Swift indexes are based on an index value of 100 for the year 1926. These indexes take into consideration the cost of machinery and major equipment plus costs for installation, fixtures, tools, office furniture, and

† For a detailed summary of various cost indexes, see *Eng. News-Record*, **178**(11):87 (1967); and *Chem. Eng.*, **70**(4):143 (Feb. 18, 1963); **73**(9)184 (April 25, 1966); **76**(10):134 (May 5, 1969); **79**(25):168 (Nov. 13, 1972); **82**(9):117 (April 28, 1975). See also the list of suggested references at the end of this chapter.

‡ Values for the Marshall and Swift equipment-cost indexes are published in each issue of *Chemical Engineering*. For a complete description of these indexes, see R. W. Stevens, *Chem. Eng.*, **54**(11):124 (Nov., 1947). See also *Chem. Eng.*, **82**(9):117 (April 28, 1975) and **85**(11):189 (May 8, 1978).

Table 3 Cost indexes as annual averages

Year	Marshall and Swift installed-equipment indexes, 1926 = 100		*Eng. News-Record* construction index			Nelson refinery construction index, 1946 = 100	Chemical engineering plant cost index 1957–1959 = 100
	All-industry	Process-industry	1913 = 100	1949 = 100	1967 = 100		
1964	242	241	936	196	87	252	103
1965	245	244	971	204	91	261	104
1966	253	252	1019	214	95	273	107
1967	263	260	1070	224	100	287	110
1968	273	268	1155	242	108	304	114
1969	285	283	1269	266	119	329	119
1970	303	301	1385	290	129	365	126
1971	321	321	1581	331	148	406	132
1972	332	332	1753	368	164	439	137
1973	344	344	1895	397	177	468	144
1974	398	403	2020	423	189	523	165
1975	444	452	2212	464	207	576	182
1976	472	479	2401	503	224	616	192
1977	505	514	2577	540	241	653	204
1978	545	554	2776	578	258	701	219
1979 (Jan.)	561†	569	2872	598	267	729	230

† All costs presented in this text are based on this value of the Marshall and Swift index unless otherwise indicated.

Table 3a Labor and material indexes as annual averages

(Basis: 1967 = 100. Construction Materials Producer Price Index and Hourly Earnings Index for Construction Workers. Adapted from *Monthly Labor Review*)

	Year							
	1964	1965	1966	1967	1968	1969	1970	1971
Labor index	86	90	95	100	107	116	128	139
Materials index	95	96	99	100	106	112	113	120

	Year							
	1972	1973	1974	1975	1976	1977	1978	Jan. 1979
Labor index	147	155	164	176	187	197	210	218
Materials index	127	139	161	174	188	205	228	241

other minor equipment. All costs reported in this text are based on a Marshall and Swift all-industry index of 561 as reported for January 1, 1979 unless indicated otherwise.

Engineering News-Record Construction Cost Index†

Relative construction costs at various dates can be estimated by use of the *Engineering News-Record* construction index. This index shows the variation in labor rates and materials costs for industrial construction. It employs a composite cost for 2500 lb of structural steel, 1088 fbm of lumber, 6 bbl of cement, and 200 h of common labor. The index is usually reported on one of three bases: an index value of 100 in 1913, 100 in 1949, or 100 in 1967.

Nelson Refinery Construction Cost Index‡

Construction costs in the petroleum industry are the basis of the Nelson construction index. The total index percentages are weighted as follows: skilled labor, 30; common labor, 30; iron and steel, 24; building materials, 8; and miscellaneous equipment, 8. An index value of 100 is used for the base year of 1946.

Chemical Engineering Plant Cost Index§

Construction costs for chemical plants form the basis of the *Chemical Engineering* plant cost index. The four major components of this index are weighted by percentage in the following manner: equipment, machinery, and supports, 61; erection and installation labor, 22; buildings, materials, and labor, 7; and engineering and supervision, 10. The major component, equipment, is further subdivided and weighted as follows: fabricated equipment, 37; process machinery, 14; pipe, valves, and fittings, 20; process instruments and controls, 7; pumps and compressors, 7; electrical equipment and materials, 5; and structural supports, insulation, and paint, 10. All index components are based on 1957–1959 = 100.

† The *Engineering News-Record* construction index appears weekly in the *Engineering News-Record*. For a complete description of this index and the revised basis, see *Eng. News-Record*, **143**(9):398 (1949); **178**(11):87 (1967). History is in March issue each year; for example, see *Eng. News-Record*, **200**(12):69 (March 23, 1978).

‡ The Nelson refinery construction index is published the first week of each month in the *Oil and Gas Journal*. For a complete description of this index, see *Oil Gas J.*, **63**(14):185 (1965); **63**(27):117 (1965); **65**(20):97 (1967); **74**(48):68 (1976).

§ The *Chemical Engineering* plant cost index is published every other week in *Chemical Engineering*. A complete description of this index is in *Chem. Eng.*, **70**(4):143 (Feb. 18, 1963) with recapping and updating in issues of **73**(9):184 (April 25, 1966); **76**(10):134 (May 5, 1969); **79**(25):168 (Nov. 13, 1972); and **82**(9):117 (April 28, 1975).

Other Indexes and Analysis

There are numerous other indexes presented in the literature which can be used for specialized purposes. For example, cost indexes for materials and labor for various types of industries are published monthly by the U.S. Bureau of Labor Statistics in the *Monthly Labor Review*. These indexes can be useful for special kinds of estimates involving particular materials or unusual labor conditions. Another example of a cost index which is useful for world-wide comparison of cost changes with time is the *EPE Plant Cost Indices International* (*1970 = 100*) published periodically in *Engineering and Process Economics*. This presents cost indexes for plant costs for various countries in the world including Australia, Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, South Africa, Spain, Sweden, the United Kingdom, and the United States.

Unfortunately, all cost indexes are rather artificial; two indexes covering the same types of projects may give results that differ considerably. The most that any index can hope to do is to reflect average changes. The latter may at times have little meaning when applied to a specific case. For example, a contractor may, during a slack period, accept a construction job with little profit just to keep his construction crew together. On the other hand, if there are current local labor shortages, a project may cost considerably more than a similar project in another geographical location.

For use with process-equipment estimates and chemical-plant investment estimates, the *Marshall and Swift* equipment cost indexes and the *Chemical Engineering* plant cost indexes are recommended. These two cost indexes give very similar results, while the *Engineering News-Record* construction cost index, relative with time, has increased much more rapidly than the other two because it does not include a productivity improvement factor. Similarly, the Nelson refinery construction index has shown a very large increase with time and should be used with caution and only for refinery construction.

COST FACTORS IN CAPITAL INVESTMENT

Capital investment, as defined earlier, is the total amount of money needed to supply the necessary plant and manufacturing facilities plus the amount of money required as working capital for operation of the facilities. Let us now consider the proportional costs of each major component of fixed-capital investment as outlined previously in Table 1 of this chapter. The cost factors presented here are based on a careful study by Bauman and associates† plus additional

† H. C. Bauman, "Fundamentals of Cost Engineering in the Chemical Industry," Reinhold Publishing Corporation, New York, 1964.